NAKHLA: A MARTIAN METEORITE WITH INDIGENOUS ORGANIC CARBONACEOUS FEATURES

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The Nakhla meteorite possesses discrete, well defined, structurally coherent morphologies of carbonaceous phases present within iddingsite alteration zones. Based upon both isotopic measurements and analysis of organic phases the presence of pre-terrestrial organics is now recognized. Within the microcrystalline layers of Nakhla's iddingsite, discrete clusters of salt crystals are present. These salts are predominantly halite (NaCl) with minor $MgCl_2$ crystals. Some $CaSO_4$, likely gypsum, appears to be partially intergrown with some of the halite. EDX mapping shows discrete C-rich features are interspersed among these crystals.

A hollow semi-spherical 'bowl' structure (~ 3µm) has been identified and analyzed after using a focused ion beam (FIB) to cut a transverse TEM thin section of the feature and the underlying iddingsite. TEM/EDX analysis reveals that the feature is primarily carbonaceous containing *C* with lesser amounts of *Si*, *S*, *Ca*, *Cl*, *F*, *Na*, and minor *Mn* and *Fe*; additionally a small peak consistent with *N*, which has been previously seen in Nakhla carbonaceous matter, is also present. Selected area electron diffraction (SAED) shows that this *C*-rich material is amorphous (lacking any long-range crystallographic order) and is not graphite or carbonate. Micro-Raman spectra acquired from the same surface from which the FIB section was extracted demonstrate a typical kerogen-like D and G band structure with a weak absorption peak at 1350 and a stronger peak at 1600 cm^{-1}. The *C*-rich feature is intimately associated with both the surrounding halite and underlying iddingsite matrix.

Both iddingsite and salts are interpreted as having formed as evaporate assemblages from progressive evaporation of water bodies on Mars. This assemblage, *sans* the carbonaceous moieties, closely resembles iddingsite alteration features previously described which were interpreted as indigenous Martian assemblages. These distinctive macromolecular carbonaceous structures in Nakhla may represent one of the sources of the high molecular weight organic material previously identified in Nakhla.

While we do not speculate on the origin of these unique carbonaceous structures, we note that the significance of such observations is that it may allow us to construct a *C*-cycle for Mars based on the *C* chemistry of the Martian meteorites with obvious implications for astrobiology and the prebiotic evolution of Mars. In any case, our observations strongly suggest that organic *C* exists as micrometer-size, discrete structures on Mars.

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